Exhibit 6

Exhibit 15 – Grape-3

'156 Patent

Claim Limitation (Claim 7)	Exemplary Disclosure
[**156a**] A device comprising:	Okumura, et al's *GRAPE-3: Highly Paralellized Special-purpose Computer for Gravitational Many-body Simulations*, discloses a device. *See, e.g.*: "We have developed a highly parallelized special-purpose computer GRAPE(GRAvity PipE)-S for gravitational many-body simulations. GRAvity PipE)-S for gravitational many-body simulations. It accelerates gravitational force calculations which is the most expensive part of the many-body simulations. The peak computing speed is equivalent to about 15 Gflops. The GRAPE-S system consists of two identical boards connected to a host computer (workstation) through VME bus. Each board has 24 custom LSI chips (GRAPE chips) which calculate gravitational forces in parallel." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 151.
[**156b**] at least one first low precision high dynamic range (LPHDR) execution unit adapted to execute a first operation on a first input signal representing a first numerical value to produce a first output signal representing a second numerical value,	GRAPE-3 discloses at least one first low precision high dynamic range (LPHDR) execution unit adapted to execute a first operation on a first input signal representing a first numerical value to produce a first output signal representing a second numerical value. *See, e.g.*: "Figure 1 shows the general concept of the GRAPE system. The special-purpose backend processor, GRAPE, is connected to a general-purpose host computer by a communication interface. The host computer sends GRAPE the positions and the masses of the particles. Then GRAPE calculates the gravitational. force on each particle, and send back the forces to the host computer." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 151.

Exhibit 15 – Grape-3

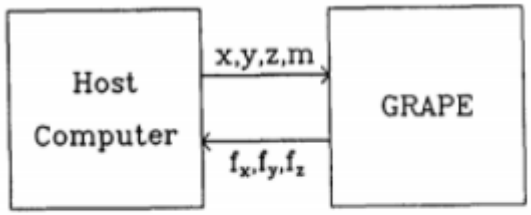
Claim Limitation (Claim 7)	Exemplary Disclosure
	 Figure 1: Basic concept of the GRAPE system.Figure 1: Basic concept of the GRAPE system. Figure 1 illustrates the inputs (*e.g.*, x,y,z,m) as well as outputs (*e.g.*, f_x,f_y,f_z). "Since we use the logarithmic format, the product of two numbers is obtained just by addition. In particular, to calculate the square, we just left-shift the input number by one bit. In a hardwired pipeline, the square operation requires no logic circuit, since this shifting realizes by connecting the lowest bit of the output to the second lowest bit of the input, second to third, etc." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 155. "GRAPE-3 consists of two identical boards. Each board has 24 GRAPE chips and calculates gravitational forces on 24 particles simultaneously [*sic*]. The structure of one GRAPE-3 board is shown in figure 3. Different GRAPE chips calculate gravitational force exerted on different particles. First the position data of all 48 particles (x_i in eq.(1)) are sent to 48 GRAPE chips. Then x_j data (j = 1, N) stored in memory is sent to all the GRAPE chips simultaniously [*sic*] and the force between the i-th and the j-th particles is calculated at every clock cycle (see §3.1.). After $N + D$ clock cycles gravitational forces exerted on 48 particles are obtained, where D is the pipeline delay. It is 19 for the GRAPE chip. The calculated forces are sent back to the host computer and the host sends the GRAPE chips the position of another 48 particles.

Exhibit 15 – Grape-3

Claim Limitation (Claim 7)	Exemplary Disclosure
	This procedure is repeated *N*/48 times to obtain the forces on all *N* particles at a given timestep. Time marching and additional calculations are performed by the host computer." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 152. As it relates to the Court's construction of LPHDR execution unit, GRAPE-3 included both addressable memory paired with the processing element(s) and control for the processing elements (to the extent that control is interpreted to include any signaling that affects the operation of the processing element). *See, e.g.*, Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 152-153 (discussing a "memory unit" in the GRAPE-3 system and stating that the "GRAPE chip" performs calculations using values "supplied from the memory unit"); *id.* at 153 (discussing the "control input pins" for the "GRAPE chip"). To the extent Singular contends that the GRAPE-3 did not include addressable memory paired with the processing element(s) and control for the processing elements, it was known to combine logarithmic-based arithmetic units such as those of GRAPE-3 with addressable memory paired with the processing element(s) and control for the processing elements (to the extent that control is interpreted to include any signaling that affects the operation of the processing element), as explained in Section IV.C.1.d of the Amended Responsive Contentions Regarding Non-Infringement and Invalidity. *See, e.g.*, Lienhart, at 3 & Fig. 1; Hamada et al., PROGRAPE-1, A Programmable, Multi-Purpose Computer for Many-Body Simulations, Publ. Astron. Soc. Japan 52 (2000), at 945-946. To the extent Singular nonetheless contends that one of skill in the art would have needed a motivation to combine processing elements with logarithmic-based arithmetic with paired addressable memory and/or control, one of skill in the art would have been motivated to do so based on the teachings of any of Lienhart, Hamada, Dockser, Belanović, Belanović and Leeser, Shirazi, the admitted prior art, Patterson & Hennessy, in Computer Organization & Design, The Hardware Software Interface (3d. Ed. 2005), and/or Cray T3D
[**156c**] wherein the dynamic range of the possible valid inputs to the first operation is at least as wide as	GRAPE-3 discloses the dynamic range of the possible valid inputs to the first operation is at least as wide as from 1/1,000,000 through 1,000,000 and for at least X=5% of the possible valid inputs to the first operation, the statistical mean, over repeated execution of the first

Exhibit 15 – Grape-3

Claim Limitation (Claim 7)	Exemplary Disclosure
from 1/1,000,000 through 1,000,000 and for at least X=5% of the possible valid inputs to the first operation, the statistical mean, over repeated execution of the first operation on each specific input from the at least X% of the possible valid inputs to the first operation, of the numerical values represented by the first output signal of the LPHDR unit executing the first operation on that input differs by at least Y=0.05% from the result of an exact mathematical calculation of the first operation on the numerical values of that same input; and	operation on each specific input from the at least X% of the possible valid inputs to the first operation, of the numerical values represented by the first output signal of the LPHDR unit executing the first operation on that input differs by at least Y=0.05% from the result of an exact mathematical calculation of the first operation on the numerical values of that same input. *See, e.g.*: "The format of position data is 20-bit fixed-point 2's-complement format. To avoid overflow, the input position must be scaled to the range (-2^{18} , 2^{18}). The mass data is expressed in the 14-bit logarithmic format. In the logarithmic format used in the GRAPE chip, an integer number l represents a real number r given by $r = 2^{1/32}$. We adopted 14-bit format for l. The lower 12 bits express the logarithm. The 13th bit indicates whether the number is zero or non-zero, and the 14th bit indicates the sign." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 153. "Figure 9 shows the theoretical relative error expressed by equation as well as the error obtained on the software simulator of the GRAPE chip, which gives the result equal to that calculated on a GRAPE chip at the bit level. The experimental error is obtained by averaging the squared deviation of the calculated force from the 'exact' force over the orientation angle. The 'exact' force is the force calculated using IEEE-754 standard 64-bit arithmetic. The value of the softening parameter, f, is 0 for both "exact" calculations and calculations on the simulator. The theoretical estimate and the experimental result are in excellent agreement. For large r, the experimental error is slightly larger than the theoretical value, since we neglected the error caused by the conversion from the logarithmic format to the fixed point format in the force accumulation module. For $r > 0.1$, the relative error is about 2 %." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 159.

Exhibit 15 – Grape-3

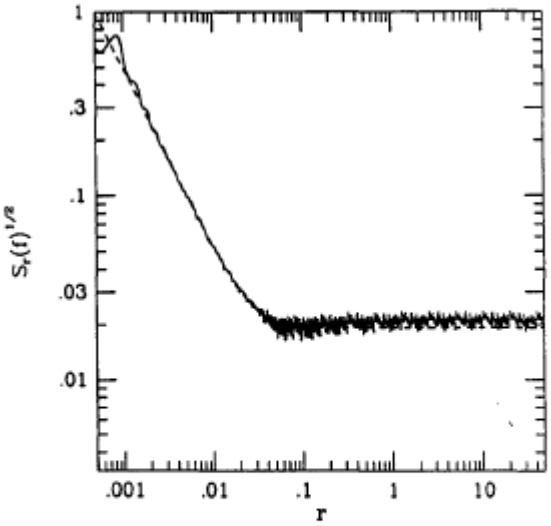
Claim Limitation (Claim 7)	Exemplary Disclosure
	 **Figure 9: Relative error of the GRAPE-3 system as a function of relative distance between a pair of particles. Dashed line is theoretical estimate of relative error expected by eq.(14), and solid line is the experimantal result obtained on the software simulator.** "We adopted the word lengths shorter than that used on conventional computers for the GRAPE chip. The word length directly determines the number of transistors and the width of the data bus. To achieve high performance in low cost, it is crucial to use the minimum word length that ensures the validity of the calculation." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 158. *See also* John N. Mitchell, Jr , *Computer Multiplication and Division Using Binary*

Exhibit 15 – Grape-3

Claim Limitation (Claim 7)	Exemplary Disclosure
	Logarithms, IRE Transactions On Electronic Computers, 512-17 (Aug. 1962) (detailing error analysis for multiplication operations with LNS formats).

Exhibit 15 – Grape-3

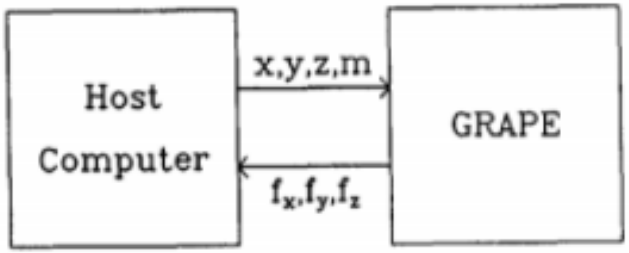
[**156d**] at least one first computing device adapted to control the operation of the at least one first LPHDR execution unit;	GRAPE-3 discloses at least one first computing device adapted to control the operation of the at least one first LPHDR execution unit. *See, e.g.*: "The host computer controls all the communication with the GRAPE-3 boards. First the position and mass of all the particles are *broadcasted* to the memories of two boards. In this case, the interface unit of only one GRAPE-3 board performs the handshake with the host computer. Then for each board, the host writes the position and mass of 24 particles to 24 GRAPE chips. After that the host sends the calculation start signal to each board. The GRAPE chips on a board simultaniously [*sic*] start the force calculation. Each GRAPE-3 board has a flag bit to indicate whether the GRAPE chips are in operation or not. The host keeps reading this flag until it is cleared. After the calculation is finished, the resultant force and potential on 24 particles are sent from each board to the host computer." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 156. "GRAPE, is connected to a general-purpose host computer by a communication interface. The host computer sends GRAPE the positions and the masses of the particles. Then GRAPE calculates the gravitational. force on each particle, and send back the forces to the host computer." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 151.  **Figure 1: Basic concept of the GRAPE system.**

Exhibit 15 – Grape-3

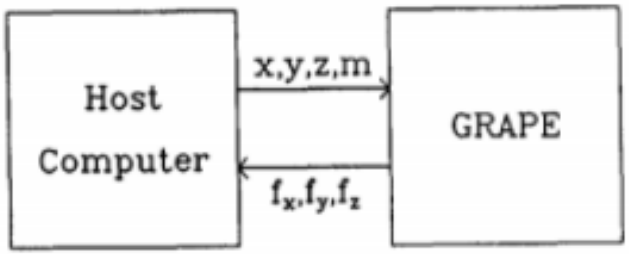
Claim Limitation (Claim 7)	Exemplary Disclosure
	 **Figure 1: Basic concept of the GRAPE system.** "GRAPE-3 consists of two identical boards. Each board has 24 GRAPE chips and calculates gravitational forces on 24 particles simultaneously [*sic*]. The structure of one GRAPE-3 board is shown in figure 3. Different GRAPE chips calculate gravitational force exerted on different particles. First the position data of all 48 particles (x_i in eq.(1)) are sent to 48 GRAPE chips. Then x_j data (j = 1, N) stored in memory is sent to all the GRAPE chips simultaniously [*sic*] and the force between the i-th and the j-th particles is calculated at every clock cycle (see §3.1.). After $N + D$ clock cycles gravitational forces exerted on 48 particles are obtained, where Dis the pipeline delay. It is 19 for the GRAPE chip. The calculated forces are sent back to the host computer and the host sends the GRAPE chips the position of another 48 particles. This procedure is repeated N/48 times to obtain the forces on all N particles at a given timestep. Time marching and additional calculations are performed by the host computer." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 152.
[**156e**] wherein the at least one first computing device comprises at least one of a central processing unit (CPU), a graphics processing	GRAPE-3 discloses at least one first computing device comprises at least one of a central processing unit (CPU), a graphics processing unit (GPU), a field programmable gate array (FPGA), a microcode-based processor, a hardware sequencer, and a state machine. Specifically, GRAPE-3 discloses a "Host Computer" that is at least a "state machine" and/or

Exhibit 15 – Grape-3

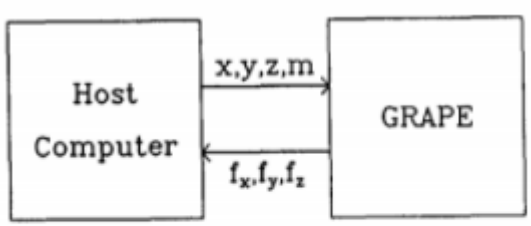
Claim Limitation (Claim 7)	Exemplary Disclosure
unit (GPU), a field programmable gate array (FPGA), a microcode-based processor, a hardware sequencer, and a state machine;	includes a CPU. *See, e.g.*: "The special-purpose backend processor, GRAPE, is connected to a general-purpose host computer by a communication interface. The host computer sends GRAPE the positions and the masses of the particles." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 151.  Figure 1: Basic concept of the GRAPE system. One of skill in the art would have understood the "Host Computer" to be at least a state machine and/or to include a CPU (perhaps alongside an GPU or FPGA, among other elements). To the extent Singular contends that GRAPE-3 does not disclose at least a state machine and/or CPU, those would have been obvious types of computing devices adapted to control the operation of the at least one first LPHDR execution unit in light of the subsequent GRAPE-6 system in 2003: "For host computers, we currently use PCs with AMD Athlon XP 1800 + CPU and SiS 745 chipset." Makino et al, *GRAPE-6: Massively-parallel Special-Purpose Computer for Astrophysical Particle Simulations* at 1165.
[**156f**] and, wherein the number of LPHDR execution units in the device exceeds by at least one hundred the non-negative integer	GRAPE-3 discloses the number of LPHDR execution units in the device exceeds by at least one hundred the non-negative integer number of execution units in the device adapted to execute at least the operation of multiplication on floating point numbers that are at least 32 bits wide. *See, e.g.*:

Exhibit 15 – Grape-3

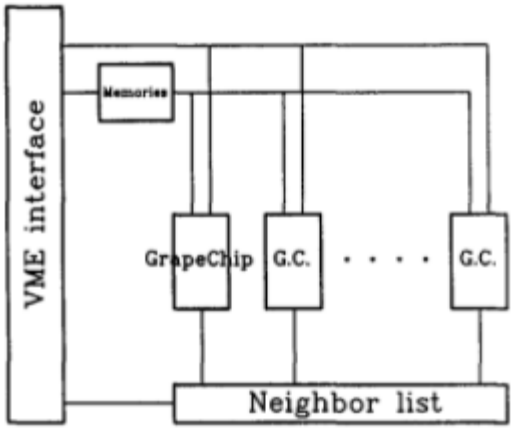
Claim Limitation (Claim 7)	Exemplary Disclosure
number of execution units in the device adapted to execute at least the operation of multiplication on floating point numbers that are at least 32 bits wide.	"GRAPE-3 consists of two identical boards. Each board has 24 GRAPE chips and calculates gravitational forces on 24 particles simultaneously [*sic*]. The structure of one GRAPE-3 board is shown in figure 3." Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 152-53.  **Figure 3: Block diagram of the GRAPE-3 system. 24 GRAPE chips on a board calculate gravitational forces and potential in parallel.**

Exhibit 15 – Grape-3

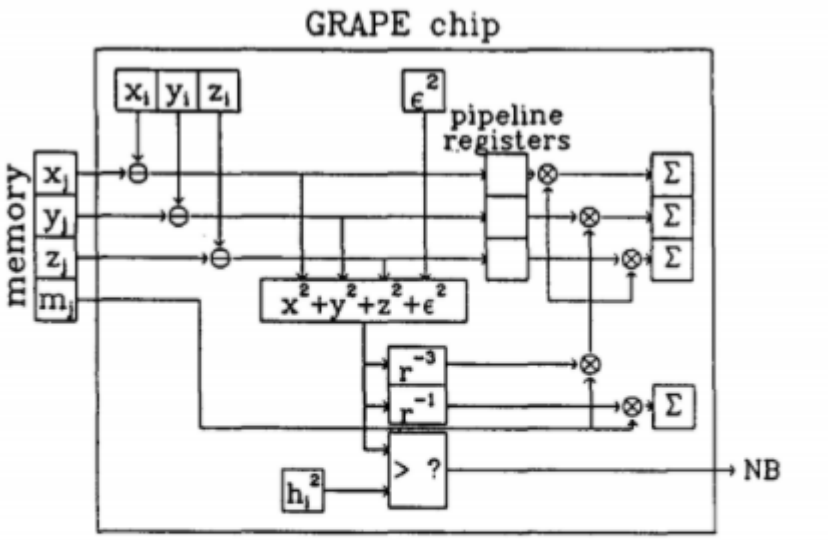
Claim Limitation (Claim 7)	Exemplary Disclosure
	Each GRAPE chip contains 17 LPHDR processing elements. Okumura, et al, *GRAPE-3 Highly Parallelized Special-purpose Computer for Gravitational Many-body Simulations* at 152.  Figure 2: Block diagram of a force calculation unit of the GRAPE system. The GRAPE chip includes modules within a large square (see §3.1.1.). Thus, each GRAPE-3 system has a total of 816 LPHDR execution units (17 processing elements per chip * 48 chips).

Exhibit 15 – Grape-3

'273 Patent

Claim Limitation (Claim 53)	Exemplary Disclosure
[**273a**] A device:	GRAPE-3 discloses a device. *See* [**156a**].
[**273b**] comprising at least one first low precision high-dynamic range (LPHDR) execution unit adapted to execute a first operation on a first input signal representing a first numerical value to produce a first output signal representing a second numerical value,	GRAPE-3 discloses at least one first low precision high dynamic range (LPHDR) execution unit adapted to execute a first operation on a first input signal representing a first numerical value to produce a first output signal representing a second numerical value. *See* [**156b**].
[**273c**] wherein the dynamic range of the possible valid inputs to the first operation is at least as wide as from 1/1,000,000 through 1,000,000 and for at least X=5% of the possible valid inputs to the first operation, the statistical mean, over repeated execution of the first operation on each specific input from the at least X % of the possible valid inputs to the first operation, of the numerical values represented by the first output signal of the LPHDR unit executing the first operation on that input differs by at least Y=0.05% from the result of an exact mathematical calculation of the first operation on the numerical values of that same input;	GRAPE-3 discloses the dynamic range of the possible valid inputs to the first operation is at least as wide as from 1/1,000,000 through 1,000,000 and for at least X=5% of the possible valid inputs to the first operation, the statistical mean, over repeated execution of the first operation on each specific input from the at least X% of the possible valid inputs to the first operation, of the numerical values represented by the first output signal of the LPHDR unit executing the first operation on that input differs by at least Y=0.05% from the result of an exact mathematical calculation of the first operation on the numerical values of that same input. *See* [**156c**]; *see also* Appendix to Responsive Contentions (detailing error rates associated with different input formats).
[**273d**] wherein the number of LPHDR execution units in the device exceeds by at least one hundred the non-negative integer number of execution units in the device adapted to execute at least the operation of multiplication on floating point numbers that are at least 32 bits wide.	GRAPE-3 discloses the number of LPHDR execution units in the device exceeds by at least one hundred the non-negative integer number of execution units in the device adapted to execute at least the operation of multiplication on floating point numbers that are at least 32 bits wide. *See* [**156f**]

Exhibit 15 – Grape-3

'961 Patent

Claim Limitation (Claim 4)	Exemplary Disclosure
[**961a**] A device comprising:	GRAPE-3 discloses a device. *See* [**156a**].
[**961b**] at least one first low precision high-dynamic range (LPHDR) execution unit adapted to execute a first operation on a first input signal representing a first numerical value to produce a first output signal representing a second numerical value,	GRAPE-3 discloses at least one first low precision high dynamic range (LPHDR) execution unit adapted to execute a first operation on a first input signal representing a first numerical value to produce a first output signal representing a second numerical value. *See* [**156b**].
[**961c**] wherein the dynamic range of the possible valid inputs to the first operation is at least as wide as from 1/1,000,000 through 1,000,000 and for at least X=10% of the possible valid inputs to the first operation, the statistical mean, over repeated execution of the first operation on each specific input from the at least X% of the possible valid inputs to the first operation, of the numerical values represented by the first output signal of the LPHDR unit executing the first operation on that input differs by at least Y=0.2% from the result of an exact mathematical calculation of the first operation on the numerical values of that same input; and	GRAPE-3 discloses the dynamic range of the possible valid inputs to the first operation is at least as wide as from 1/1,000,000 through 1,000,000 and for at least X=5% of the possible valid inputs to the first operation, the statistical mean, over repeated execution of the first operation on each specific input from the at least X% of the possible valid inputs to the first operation, of the numerical values represented by the first output signal of the LPHDR unit executing the first operation on that input differs by at least Y=0.05% from the result of an exact mathematical calculation of the first operation on the numerical values of that same input. *See* [**156c**]; *see also* Appendix to Responsive Contentions (detailing error rates associated with different input formats).
[**961d**] at least one first computing device adapted to control the operation of the at least one first LPHDR execution unit.	GRAPE-3 discloses at least one first computing device adapted to control the operation of the at least one first LPHDR execution unit. *See* [**156d**].

Exhibit 15 – Grape-3

Claim Limitation (Claim 13)	Exemplary Disclosure
[**961e**] A device comprising:	GRAPE-3 discloses a device. *See* [**156a**].
[**961f**] a plurality of components comprising:	GRAPE-3 discloses a plurality of components. *See* [**156b**] + **[156d**].
[**961g**] at least one first low precision high-dynamic range (LPHDR) execution unit adapted to execute a first operation on a first input signal representing a first numerical value to produce a first output signal representing a second numerical value,	GRAPE-3 discloses at least one first low precision high-dynamic range (LPHDR) execution unit adapted to execute a first operation on a first input signal representing a first numerical value to produce a first output signal representing a second numerical value. *See* [**156b**].
[**961h**] wherein the dynamic range of the possible valid inputs to the first operation is at least as wide as from 1/1,000,000 through 1,000,000 and for at least X=10% of the possible valid inputs to the first operation, the statistical mean, over repeated execution of the first operation on each specific input from the at least X% of the possible valid inputs to the first operation, of the numerical values represented by the first output signal of the LPHDR unit executing the first operation on that input differs by at least Y=0.2% from the result of an exact mathematical calculation of the first operation on the numerical values of that same input.	GRAPE-3 discloses the number of LPHDR execution units in the device exceeds by at least one hundred the non-negative integer number of execution units in the device adapted to execute at least the operation of multiplication on floating point numbers that are at least 32 bits wide. *See* [**156c**]; *see also* Appendix to Responsive Contentions (detailing error rates associated with different input formats).